THE APPROACHING TOTAL ECLIPSE OF THE SUN.[1]

III.

The Work proposed for the Indian Eclipse.

AMONG the work proposed to be carried on during the eclipse of 1896, it may be well imagined that the employment of the prismatic camera occupied a large place, but, unfortunately, the weather allowed no observation to be made by those of 6 inches and 9 inches aperture I took out to Kiö ; the instrument employed in Brazil in 1893 was, however, again successful in the hands of Mr. Shackleton in Novaya Zemlya.

With regard to the work I propose to attempt in India, the following extracts from a letter I was called upon to write some time ago, still express my views. These are based upon the results obtained with the prismatic cameras in 1893 and 1896, which, although they are not yet fully worked out, in my opinion far transcend in importance any observations made on the eclipsed sun since 1868 :—

"(1) I propose in 1898 to use a prismatic camera with double the present dispersion, although the dispersion employed by me in 1893 and 1896 was, I believe, far beyond anything obtained before.

"The facts are as follows. With the 6-inch prismatic camera used in 1893, the photographed spectrum was 3·1 inches long from D to K. With the 9-inch, which it was proposed to employ in 1896, the corresponding length of spectrum was 3·9 inches ; while with the 3-inch prismatic camera actually used in Novaya Zemlya, the spectrum was 2·9 inches long from D to K.

"I believe the next highest dispersion obtained before was by Captain Hills in 1893, and by Dr. Schuster in 1886. Data are not available for exactly comparing the dimensions of the spectra then photographed with those stated above, but they were certainly considerably smaller in both cases.

"The imperative necessity for this increased dispersion may be gathered from the following facts concerning the spectrum of iron which I have best studied, and on which I have thousands of unpublished observations to compare with an eclipse spectrum when we can get one on a sufficient scale.

"Taking Rowland's lines, it may be generally stated that, on an average, one occurs at every 6/10 of a tenth-metre, the unit of measurement generally employed in such matters. With the dispersion in my photographs—the greatest so far obtained, as I have explained—we do not feel ourselves justified in assuming a greater accuracy than 5/10 of a unit. Evidently then, so far as this line of work alone is concerned, we can make no definite statements as to the presence or absence of iron lines in the eclipse photographs.

"So far as I am aware, no observations with the slit spectroscope will enable us to determine with any kind of exactness the relative composition of the successive layers of the sun's gaseous envelope. The difficulty chiefly arises, as I pointed out in 1882, from the fact that we have to deal with the projection of a sphere surrounded by vapours, and not with a section.

"On the other hand, the photographs taken with the prismatic cameras in 1893, and during the last eclipse, show clearly that there are essential differences in the composition of the envelopes at different levels, and the limits of various layers are indicated ; but the dispersion is too small to enable us to define the chemical origins of the layers with sufficient certainty. A full statement of the evidence upon this point is included in the report on the results obtained with the prismatic cameras in 1893, which is now in the press.[2]

"(2) The prismatic camera has enabled us to photograph radiations at many different wave-lengths in the spectrum of the corona, differentiating them absolutely from the radiations of the chromosphere and prominences. This is a gigantic advance. But, in the prismatic camera photographs, the indications, except in the case of the 1474 ring, and two or three others, are very dim.

"It is important, therefore, to employ an integrating spectroscope of large dimensions to attempt to get stronger indications of these radiations *by utilising the greater area of the corona*, which of course the prismatic camera cannot do.

"(3) I may say, roughly, that in the (still unpublished) spectrum of the chromosphere obtained in 1893 and 1896, we deal with less than 10 per cent. of the Fraunhofer lines. It is of the first importance, then, to search for the others. I certainly saw some of them in 1882, but a very special inquiry is necessary. This I therefore include in my programme. These lines are certain to be dim, otherwise we should have photographed them already. The tendency of the observations of 1893 and 1896 is to show that they will be found in all probability above the chromospheric layer we have photographed, and associated with the coronal layers, of which we have photographed a few of the brightest radiations.

"The thicknesses of the chromospheric layers have been :—

	1893.	1896.
H and K	less than 5000 miles.	5000 miles.
G	3000 ,,	
4471	,, 3000 ,,	
Strontium line 4077	500 ,,	
Iron triplet ...	,, 500 ,,	
Shortest arcs of Fe, &c.	,, 500 ,,	90 miles.

"Beyond the dark moon, both in 1893 and 1896, we have indications of luminosity in the prismatic camera photographs, but no final statement can be made as to its origin.

"This gives us the spectrum of a part of the solar atmosphere at a great height :—

1893 ... 22,500 miles to 600,000 miles.
1896 ... 14,000 ,, to a height not yet determined.

"This, therefore, indicates a region, some 10,000 of miles in thickness, to be also explored, and the blank in the photographic evidence so far obtained suggests that eye observations must be employed.

"It will be seen from the above statement that the three parts of the proposed inquiry are all strictly connected, and that to employ any one of them without the others would greatly weaken the attack."

It will have been gathered that the chief object of the above observations is to determine the chemical and physical conditions of that part of the sun's atmosphere just above the photosphere, and therefore including the chromosphere.

Why so much importance is attached to such observations during eclipses, is that ordinary daily observations on the uneclipsed sun, although they carry us far, do not carry us far enough.

The results once obtained are not limited to the sun, they find their application in the study of every star in the heavens ; it is, indeed, now recognised that observations of eclipses, such as those made in 1882, 1893, and 1896, provide us with a series of facts with which to approach the question of the absorption phenomena presented by the stars, and the whole question of the classification of stars depends almost absolutely upon their absorption phenomena.

In many of these bodies the atmosphere may be millions of miles high ; in each star the chemical substances in the hottest and coolest portions may be vastly different ; the region, therefore, in which the absorption takes place which, spectroscopically, enables us to discriminate star from star, must be accurately known before we can obtain the greatest amount of information from our inquiries.

I may say that for some time I was of opinion that in the sun many of the darkest lines indicated absorptions high up in the atmosphere, for the reason that the bright continuous spectrum of the lower levels might have an important effect upon line absorption phenomena by superposing radiation, and so diminishing the initial absorption. The observations of the eclipse of 1893, however, indicate that this opinion is probably only strictly true when the strata of the sun's atmosphere not too high above the photosphere are considered.

If we are justified in arguing from a star with a photosphere as well developed as that of the sun to one in which it is in all probability much less marked in consequence of a much higher temperature, then we must consider that the absorptions which define the various star groups are more conditioned by the temperatures of the hottest regions merely than by the thickness of the absorbing atmospheres, or by the densities of the various vapours. Another consideration to be borne in mind is that if the atmospheres are in part composed of condensable vapours, and not entirely of gases permanent at all stellar temperatures, condensation must always be going on outside in the region of lowest temperature.

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[1] Continued from page 178.

[2] This has since been published, and I shall refer to it later.

Hence it is important to consider the conditions of that part of the sun's atmosphere where it is known beyond all question that certain, but not all, of the absorptions which produce the Fraunhofer lines take place.

In my paper on the eclipse of 1893 (*Phil. Trans.*, 1896, vol. clxxxvii. A, p. 603), I referred at length to this point. The matter is so important that I do not hesitate to quote in the present connection what I then said :

> "As a result of solar spectroscopic observations, combined with laboratory work, Dr. Frankland and myself came to the conclusion, in 1869, that at least in one particular, Kirchhoff's theory of the solar constitution required modification. In that year we wrote as follows (*Roy. Soc. Proc.*, vol. xvii. p. 88) :—
>
> "'May not these facts indicate that the absorption to which the reversal of the spectrum and the Fraunhofer lines are due takes place in the photosphere itself, or extremely near to it, instead of in an extensive outer absorbing atmosphere ?'
>
> "In an early observation of a prominence on April 17, 1870, I found hundreds of the Fraunhofer lines bright at the base, and remarked that a 'more convincing proof of the theory of the solar constitution put forward by Dr. Frankland and myself could scarcely have been furnished' (*Roy. Soc. Proc.*, vol. xviii. p. 358).
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> "During the eclipse of 1870, at the moment of disappearance of the sun, a similar reversal of lines was noticed ; we had, to quote Prof. Young, 'a sudden reversal into brightness and colour of the countless dark lines of the spectrum at the commencement of totality.' On these observations was based the view that there was a region some 2″ high above the photosphere, which reversed for us *all* the lines visible in the solar spectrum ; and on this ground the name 'reversing layer' was given to it.
>
> "Continued observations, however, led me, in 1873, to abandon the view that the absorption phenomena of the solar spectrum are produced by any such thin stratum, and convinced me that the absorption took place at various levels above the photosphere. I need not give the evidence here ; it is set forth in my 'Chemistry of the Sun' (chap. xxii. pp. 303–309). On the latter hypothesis the different vapours exist normally at different distances above the photosphere, according to their powers of resisting the dissociating effects of heat (*Roy. Soc. Proc.*, vol. xxxiv. p. 292).
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> "My observations during the eclipse of 1882, in the seven minutes preceding totality, to my mind set the matter at rest. 'We begin with one short and brilliant line constantly seen in prominences, never seen in spots. Next another line appears, also constantly seen in prominences ; and now, for the first time, a *longer* and thinner line appears, occasionally noted as widened in spots ; while, last of all, we get, very long, very delicate relatively, two lines constantly seen widened in spots, and another line, not seen in the spark, and never yet recorded as widened in spots' (*ibid.*, vol. xxxiv. p. 297).
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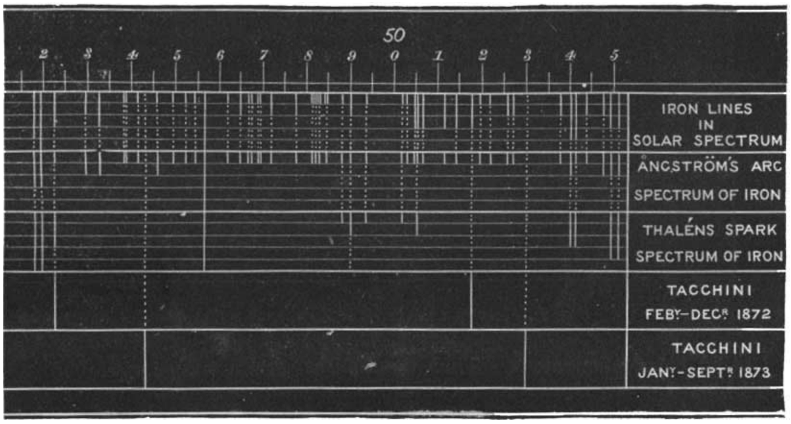
> "Similar observations in the same part of the spectrum were made by Prof. Turner in 1886 (*Phil. Trans.*, 1889, vol. clxxx. A, p. 391). His observations were made under less favourable conditions than those in Egypt, and in the absence of statements as to the relative lengths of the lines observed, it is impossible to utilise them fully.
>
> "This is one of the most important points in solar physics, but there is not yet a consensus of opinion upon it. Prof. Young and others, apparently, still hold to the view first announced by Dr. Frankland and myself in the infancy of the observations, that the Fraunhofer absorption takes place in a thin stratum, lying close to the photosphere."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IRON LINES IN SOLAR SPECTRUM
ANGSTRÖM'S ARC SPECTRUM OF IRON
THALÉNS SPARK SPECTRUM OF IRON
TACCHINI FEBY–DECR 1872
TACCHINI JANY–SEPTR 1873

FIG. 10.—Tacchini's observations of the iron lines at 4924·1 and 5018·6 on the spectrum of the quiet chromosphere in 1872. It will be observed that new prominence lines were recorded when the iron lines disappeared.

I next proceeded to discuss the numerous photographs obtained during the eclipse, and I gave a map showing that there was only the slightest relation between the intensities of the lines common to the Fraunhofer and the eclipse spectrum, and, further, that only a few of the Fraunhofer lines are represented at all. Not only this, but in the eclipse photographs there are many bright lines not represented at all among the Fraunhofer lines.

The chromosphere, then, is certainly not the origin of the Fraunhofer lines, either as regards intensity or number. From the eye observations made since 1868, I pointed out many years ago that there is evidence that the quiescent chromosphere spectrum indicates a higher temperature than that at which much of the most valid absorption takes place ; in other words, that the majority of the lines associated with lower temperature are produced above the level of the chromosphere ; while the eclipse photographs of 1893 and 1896 afford evidence by the greater length of some of the lower temperature lines that we need not locate the region which produces them at any great height above the chromosphere.

The solar evidence, then, is that most of the line absorption is produced in, and not very far above, the chromosphere. This is a conclusion we are bound to accept in a discussion of the origin of stellar absorption in the absence of evidence to the contrary. We have no right to assume that the absorption will be produced at the top of the atmosphere in one star, and in the bottom in another, when the atmospheres are once relatively quiescent.

Quite recent work has very greatly strengthened these conclusions in regard to the sun. The conclusion with regard to the high temperature of the quiescent chromosphere depended chiefly upon the Italian observations and upon investigations communicated by myself to the Royal Society in 1879 (*Roy. Soc. Proc.*, 1879, vol. xxx. p. 22), and 1881 (*ibid.*, 1881, vol. xxxii. p. 204), on the effect of high-tension electricity on the line spectra of metals (Fig. 10).

These investigations consisted in noting (1) the lines brightened in passing a spark in a flame charged with metallic vapours, and (2) the lines brightened on passing from the arc to the spark. It was found, in the case of iron, that two lines in the visible spectrum at 4924·1 and 5018·6, on Rowland's scale, were greatly enhanced in brightness with higher temperatures, and were very important in solar phenomena. Thus the line at 4924·1 was at times the only representative of iron in the chromosphere; upwards of 1000 lines in the visible spectrum of iron gave no sign.

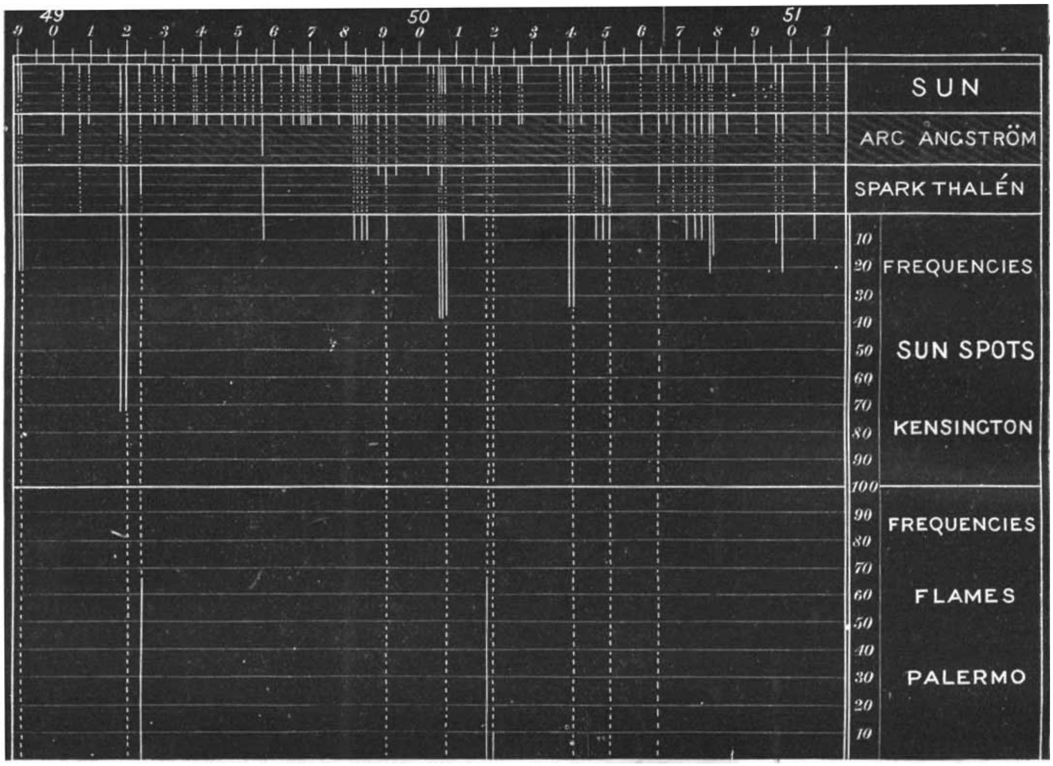

FIG. 11.—Iron spot-lines seen at Kensington confronted with iron prominence lines seen at Palermo.

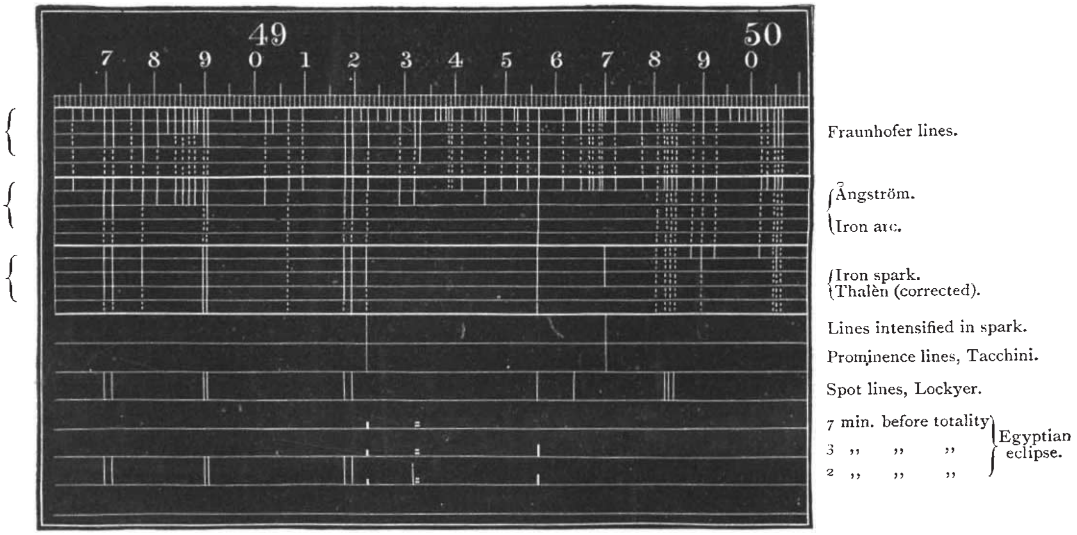

FIG. 12.—The line seen during the Solar Eclipse in 1882, showing that the prominence line at 4924·1 was seen short and bright seven minutes before totality, and some of the spot lines were not seen till two minutes before totality, and then they were observed long and dim.

Spots are conceded to be cooler phenomena than those observed in other parts of the photosphere, so we should not expect to find the hotter lines so frequent in them. Fig. 11 gives the facts. It is a comparison of the iron lines observed in spots, and in the quiet chromosphere during the same time in 1872, the spots being observed at Kensington, the chromosphere at Palermo. It will be seen that none of the lines seen in the chromosphere were seen in the spots, and *vice versâ*.

It was natural to suppose that the iron vapour producing the cooler lines was higher up than that responsible for the enhanced line at 4924·1. Hence a crucial observation was planned for the eclipse of 1882. If the vapour were higher it should be dimmer, and its lines should, if seen at all, be seen long and faint very near the beginning of totality, while the hotter line, being produced by vapours relatively low and at a higher temperature, should be seen short and bright some time before the beginning of totality.

Fig. 12 will show how absolutely the prediction was verified by the event.

J. NORMAN LOCKYER.

(*To be continued.*)

ON LUNAR AND SOLAR PERIODICITIES OF EARTHQUAKES.

THE investigation of small periodical changes is rendered difficult chiefly by the doubt which so often exists, whether the results obtained by the ordinary methods are due to accident or prove some real periodically acting cause. Attention need only be drawn to the many calculations which have been made to trace the sunspot period in terrestrial phenomena, such as rainfall or temperature, to show that widely different conclusions may be drawn from the same evidence according as greater or smaller value is attached to the element of chance. I have been engaged for some time to apply the theory of probability to investigations of this nature, with a view if possible to being able in every instance to assign a definite number to the probability that any periodicity which may be found in the record of some physical phenomenon is of an accidental nature. In a paper recently communicated to the Royal Society, I have applied the results obtained to the periodicities of earthquakes. Mr. Knott (*Proc. Roy. Soc.*, vol. lx. p. 457) has recently published some investigations, conducted with skill and labour, which in his judgment were favourable to the existence of a true lunar influence on earthquakes. The theory of probability, however, does not support that view. The number of earthquakes treated by Mr. Knott is 7427, and Fourier's series is applied to determine the amplitudes of the changes which have periods coincident with the lunar day, the half-day and the third or fourth part of a lunar day. The method employed would always give some results whether a true periodicity existed or not, and I have calculated what the average amplitudes would be if earthquakes were distributed quite at random. These amplitudes depend, of course, on the number of events taken into the calculation, and are found to vary inversely as the square root of that number. The following table will show how the amplitudes found by Mr. Knott compare with those calculated by the theory of probability. C_1 in the table refers to the lunar day, while C_2, C_3 and C_4 refer to its submultiples.

Coefficients	C_1	C_2	C_3	C_4
Expectancy for the coefficients	19·3	15·7	10·6	5·2
By the theory of probability...	10·3	17·9	10·9	3·97

As it may further be shown that cases will frequently occur where the amplitudes found are equal to twice the expectancy, the table may be considered as conclusive that if a lunar effect exists, it must be so small that it is quite hidden by accidental effects. For the present, at any rate, the evidence is against such a lunar influence. A discussion of the periods, coincident with the lunar months, leads to the same conclusion.

It is otherwise with the annual and daily periods, which have recently been discussed by Mr. Davison. Here the amplitudes found are decidedly too large to be due to accident; and we may therefore say, with a degree of probability amounting practically to certainty, that there is a yearly period giving a maximum of earthquakes in December, and a daily period giving a maximum some time between ten o'clock in the morning and noon.

ARTHUR SCHUSTER.

NOTES.

A SMALL committee has been appointed by the Treasury "to consider and report upon the desirability of establishing a National Physical Laboratory for the testing and verification of instruments for physical investigation, for the construction and preservation of standards of measurement, and for the systematic determination of physical constants and numerical data useful for scientific and industrial purposes, and to report whether the work of such an institution, if established, could be associated with any testing or standardising work already performed wholly or partly at the public cost." The following will be the members of the committee:—The Lord Rayleigh, F.R.S. (chairman), Sir Courtenay Boyle, K.C.B., Sir Andrew Noble, K.C.B., F.R.S., Sir John Wolfe Barry, K.C.B., F.R.S., Prof. W. C. Roberts-Austen, C.B., F.R.S., Mr. Robert Chalmers, of the Treasury, Prof. A. W. Rücker, F.R.S., Mr. Alexander Siemens, Dr. T. E. Thorpe, F.R.S.

AT a meeting of the Royal College of Physicians of London, on Thursday last, the College, on the recommendation of the Council, awarded the Moxon gold medal to Sir Samuel Wilks, F.R.S., the President of the College, for having especially distinguished himself by observation and research in clinical medicine, and the Baly medal to Prof. Schäfer, F.R.S., for having especially distinguished himself in the science of physiology. The Harveian oration will be delivered by Sir William Roberts on October 18, St. Luke's Day. Dr. E. Markham Skerritt, of Bristol, will give the Bradshaw lecture on November 4; and Dr. F. Pavy will deliver a special lecture, supplementary to the Croonian lectures, delivered in 1894, on November 11. The following were announced as lecturers for next year:—Goulstonian lectures, Dr. John Rose Bradford; Lumleian lectures, Sir Richard Douglas-Powell; Croonian lectures, Dr. Sidney Martin.

A PARLIAMENTARY paper has just been issued giving an additional Civil Service Estimate, amounting to 10,000*l.*, for Art and Science buildings of Great Britain. The total original net estimate for 1897–98 was 26,000*l.*, and this has been increased to 36,000*l.* The British Museum and the Science and Art Department buildings receive 5000*l.* each for new works, alterations, and additions. The increased grant to the Science and Art Department is on account of the cost of carrying out certain urgent works and services at South Kensington, designed to give effect to the recommendations made in the first report from the Select Committee on the Museums of the Department. It is proposed to remove the more dangerous buildings on the east side of Exhibition Road (including the "boilers" and the electric lighting plant), to displace the occupants of the official residences, and reconstruct the entrance to the galleries on the west side of Exhibition Road.

THE Weights and Measures Bill (Metric System), the scope of which has already been described (p. 275), was read a third time and passed in the House of Lords on Friday last.

WE notice with regret that the Hon. Ralph Abercromby, who did so much for the advancement of meteorological science, died at Sydney, New South Wales, on June 21, at fifty-four years of age.